TECHNOLOGICAL CHANGE AND ECONOMIES OF SCALE IN U.S. POULTRY SLAUGHTER

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Abstract

This paper uses a unique data set provided by the Census Bureau to empirically examine technological change and economies of scale in the chicken and turkey slaughter industries. Results reveal substantial scale economies that show no evidence of diminishing with plant size and that are much greater than those realized in cattle and hog slaughter. Additionally, it is shown that controlling for plant product mix is critical to cost estimation and animal inputs are much more elastic to prices than in either cattle or hogs. Results suggest that consolidation is likely to continue, particularly if demand growth diminishes.

JEL Number: L11-- Porduction, Pricing, and Market Structure; Size and Size Distribution of Firms.

Key words: scale economies, consolidation, chicken slaughter, turkey slaughter.

Introduction

Over the past 30 years chicken and turkey consumption has risen dramatically and has been matched by an equally impressive shift in industry structure. Almost no slaughter plants in 1963 had more than 400 employees and the dominant product was generic whole birds. By contrast, most poultry slaughter plants today have more than 400 employees and their product mix consists of cut-up and deboned poultry, traypacks, and further processed products. This paper examines the forces driving plants into larger and larger production units and illustrates the importance of controlling for product mix in cost function estimation. Results suggest that technological scale economies account for the growth in plant size, and that even the largest plants have room to grow and realize still greater increasing returns. These findings contrast sharply with findings for cattle and hog slaughter (MacDonald, et al., 2000) that show that the largest cattle and hog slaughter plants are near the limits of increasing returns to scale and that some relatively small cattle and hog slaughter plants remain competitive.

Use of Census Bureau plant-level data from 1972-92 for chicken and 1967-92 for turkey slaughter was of critical importance to accurate cost function analyses. These data permitted us to examine technological change in the context of dramatic shifts in plant size and product mix -- both of which are critical to accurate poultry plant cost function analysis.

Structural Change

Major structural changes occurred in the poultry slaughter industries over the 1967-92 period (table 1). Most importantly, production by large chicken and turkey slaughter plants as shares of total output increased from less than 30 to over 80 percent. This shift to larger plant sizes translated into impressive but less dramatic shifts in industry concentration -- less than 50 percent in both industries -- that may have been higher if it weren't for a tripling of per capita poultry consumption and the jump in chicken and turkey exports of 4,000 and 900 percents.

Major changes also occurred in slaughter plant product mix. Whereas plants mainly produced generic whole birds in the 1960s, by 1992 they were producing a host of processed and further processed, branded and nonbranded products, ranging from poultry luncheon meats to cut-up and deboned poultry. Most production of raw processed products takes place in slaughter plants, which add cut-up and processing lines to the end of existing slaughter lines. By 1992 over 70 percent of chicken and 50 percent of turkey production consisted of deboned and cut-up poultry for use in consumer- ready traypacks, restaurant products, and further processed poultry (table 2). Some slaughter plants, particularly turkey ones, produced luncheon meats and other cooked or otherwise further processed poultry, but much of it occurred in independent plants.

A Model of Chicken and Turkey Slaughter Plant Costs

Bugos, et al. (1992) assert that chicken slaughter plants had adopted the integrator organizational structure by the end of the 1960s. In this structure, the integrator owns the slaughter plant, feed mill, perhaps a further processing plant, and has a number of growers under contract. The integrator provides the grower with chicks or poults, feed, veterinary services, and other inputs, and the grower contributes housing and the labor services for raising chicks or poults to slaughter-ready birds. The integrator converts the ready-to-slaughter live birds into various raw and semi-processed ready-to-cook poultry products that are sold to retailers, wholesalers, or buyers in export markets or shipped to further processing plants for conversion into luncheon meats and other processed products.

Effort to reduce processing costs associated with converting live chickens into final consumer products has led to major changes in the size and scope of plant operations. Whereas the increase in plant throughput may have yielded scale economies, the shift in product mix from whole birds to traypacks, cut-up and deboned ready-to-cook chicken, and further processed products increased labor costs because many more laborers were required. Other technological changes also occurred. Poultry plants in the 1960s often slaughtered other poultry species, but, by 1992, almost none did; thus, avoiding costly changeovers. Additionally, turkey plants were able to change from seasonal to year-round turkey production schedules. These changes in plant technology lead us to model production costs within the following general framework,

$$1) \qquad C = f\,(Q, P_i, Z, \tau)$$

where C is total costs, Q is output, P is factor prices, Z represents firm effects, and τ is technology. Ignoring technology for now, we specify a translog cost function with output, factor prices, and firm effects as arguments and all continuous variables (C, Q, and the P_i) transformed to natural logarithms:

$$\begin{aligned} 2) \qquad \ln C = {} & \alpha_0 + \sum_i \beta_i \ln P_i + \frac{1}{2}\sum_i \sum_j \beta_{ij} \ln P_i \cdot P_j \\ & + \gamma_Q \ln Q_Q + \frac{1}{2}\gamma_{QQ}(\ln Q)^2 + \sum_i \gamma_{Qi} \ln Q \cdot \ln P_i \\ & + \delta_z Z + \sum_i \delta_{iz} Z \cdot \ln P_i + \delta_{Qz} Z \cdot \ln Q + \varepsilon \end{aligned}$$

Technological change is often represented in the translog by appending technology (τ) as a specific right hand side argument:

$$3) \qquad \tau = \alpha_1 t + \sum_i \alpha_{1i} \ln P_i * t + \alpha_3 \ln Q * t$$

where t is a simple time trend; α_1 captures neutral technological change and is interpreted as the annual rate of change of costs, holding output and prices constant. Biased technical change is captured by α_{1i} (factor biased) and α_3 (scale biased) terms.[1]

Equation (3) imposes the view that technological change causes a drop in input usage (alternatively, total costs), given factor prices and levels of output (Stevenson, 1980). Technological change should not increase costs because that would suggest technical regress or, more likely, specification error (if technological change flows from new knowledge, technical regress shouldn't occur because it implies knowledge destruction).

Chicken plants introduced several types of technological changes that more intensively used existing inputs and facilities. First, they increased plant throughput and reduced labor costs with greater capacity chill baths and automated dressing and deboning equipment. Second, they developed larger and more uniform size birds, permitting increased line speeds and more meat per bird with little or no change in labor and capital inputs. Third, plants became highly specialized by live bird species, leading to the near disappearance of slaughter plants that butcher multiple bird species and use unprocessed poultry meat rather than live birds as inputs. Fourth, changes in production scheduling enabled plants to avoid the costly

[1] The specification outlined above is linear. More flexible specifications have quadratic terms and splines, allowing the annual rate of productivity growth to vary over time.

start-ups and shutdowns associated with seasonal poultry demand, such as the end-of the-year holiday season for turkey slaughter..

But the most striking set of innovations are those that provided consumers with higher value products. This change caused a shift in the composition of product mix away from whole birds to raw deboned and cut-up poultry. Table 2 shows the trends: estimated whole bird output in chicken slaughter plants had fallen to 21% of the total by 1992, down from 72% twenty years earlier, while turkeys sold whole fell to 45% from 85%. The cut-up and deboned poultry was sometimes used within the plant in branded or private label traypacks, but most went for export, further processing, either within the plant or outside of it, or to retailers and wholesalers who packaged it into private label products. The array of the further processed products derived from the deboned poultry and cut-up poultry is enormous: ranging from patties, nuggets, and ground products to whole cooked birds, frankfurters, and luncheon meats. Product innovations require more in-plant processing and hence more labor, capital, and materials (primarily energy and packaging). Consequently, poultry product innovations will be cost raising, factor-biased (the bird meat share of total costs will fall), and scale biased because larger slaughter plants do more processing (Ollinger et al, 2000).[2]

The presence of both cost-reducing and cost-raising technological change requires a cost function that accounts for both changes. Improvements in production processes and bird characteristics are assumed to follow a spline function in which various periods are considered independently. We choose

[2] Product innovations interact with process innovations. Greater demand for white meat spurred the development of larger birds with relatively more white meat. Food service demands for processed products led to a greater emphasis on uniformity. Greater size and uniformity in turn allowed for adoption of new equipment that lowered processing costs.

the more flexible spline function rather than a time trend because it isolates every period and permits us to distinguish cost-raising technological change, as reflected in product class data, from cost-reducing technological change.

Equation 4 represents technological change with a spline function:

$$
\begin{aligned}
4)\qquad \tau = {} & \sum_k \alpha_{1k} T_k + \sum_j \delta_{1j} t_j + \frac{1}{2} \sum_j \sum_l \delta_{jl} \ln t_j \cdot \ln t_l + \sum_i \sum_j \delta_{ij} \ln P_i \cdot \ln t_j \\
& + \sum_j \delta_{Qj} \ln Q \cdot \ln t_j + \sum_i \sum_k \alpha_{1ik} \ln P_i \cdot T_k \\
& + \sum_k \alpha_{Qk} \ln Q \cdot T_k + \sum_j \sum_k \alpha_{2jk} \ln t_j \cdot T_k
\end{aligned}
$$

where T_k denotes different Census periods, t_j represents specific types of technological change, including plant specialization by live bird species, scheduling changes, and product innovations. Product innovations are cost raising, while the others are cost lowering.

Estimation Issues

Following standard practice, we impose symmetry and homogeneity of degree one on the cost function, such that $\beta_{ij}=\beta_{ji}$; $\alpha_{ki} = \alpha_{ik}$; $\gamma_{Qi} = \gamma_{Qi}$; $\delta_{iZ} = \delta_{Zi}$ for all I, j, and k and $\sum \beta_i=0$, $\sum \beta_{ij}=\sum \alpha_{ik}=\sum \gamma_{Qi}=\sum \delta_{iZ} = 0$. Since all variables are divided by their mean values, the first order factor price terms (β_i) can be interpreted as cost shares at mean values. The other coefficients capture changes in factor prices, output, plant characteristics, and technology with deviations from sample mean values.

Efficiency gains are achieved by estimating the factor demand (cost share) equations (5) jointly with the cost function with a Seemingly Unrelated Regression econometric model. The capital cost share equation was dropped because the cost share equations sum to one.

$$5) \quad \frac{\partial lnC}{\partial lnP_i} = \frac{P_iX_i}{C} = \beta_i + \sum_j \beta_{ij}\ln P_j + \gamma_{Qi}\ln Q + \delta_{iz}Z + \sum_k \alpha_{1ik}T_k + \sum_l \alpha_{li}t_l$$

The derivative of the cost function yields the cost elasticity (equation 6). A value of ε_{CQ} of less than 1 gives evidence of economies of scale and values in excess of 1 show diseconomies of scale. The coefficient for the first order output term, γ_{Q}, gives the cost elasticity at the sample mean, and the coefficient on the second order output term, γ_{QQ}, indicates how scale economies vary with plant size. Other coefficients show how scale economies change with changes in factor prices, firm effects, and technologies.

$$6) \quad \varepsilon_{CQ} = \frac{\partial lnC}{\partial lnQ} = \gamma_Q + \gamma_{QQ}\ln Q + \sum_i \rho_{iQ}\ln P_i + \delta_{Qz}Z + \sum_k \alpha_{1Qk}t_k + \sum_l \alpha_{3Ql}t_l$$

Cost-increasing technological change resulted from the introduction of products processed beyond whole birds, including chicken traypacks, semi-processed products and many others. Census data contain several categories of these products, including whole birds and cut-up products in wet and dry ice bulk containers, turkey parts (only for 1987 and 1992), chicken traypacks (1972-92), poultry frankfurters and other further processed products, nonclassified items, and other broilers and old hens, roasters and capons.

Differences in product mix could be accommodated econometrically by extending the cost function to the multi-product framework (Baumol, Panzar, and Willig, 1982). However, since many poultry slaughter plants produce zero amounts of some inputs, this model fails in the translog form. Thus, we follow an approach commonly used in trucking and transportation cost function analyses, such as Allen and Lieu (1995), in which product mix variables are introduced into a single-product translog framework. Cost elasticities with respect to product mix indicate how changes in mix affect costs. Additionally, coefficients on the interaction of product mix with size provide evidence of economies of scope.

Data

We use the data records of individual establishments reported in the Census of Manufactures' Longitudinal Research Database (LRD) for each of the quintenial censuses from 1972-92 for chicken and 1967-92 for turkey (data from the 1997 Census will be processed for the LRD too late for this report). The LRD covers all plants with more than 20 employees. Data include the 694 chicken slaughter plants and the 314 turkey slaughter plants that slaughter chickens or turkeys, report product mix data, and have more than 50 percent of their total value of shipments from chicken or turkey slaughter products.

Census data prior to 1967 were excluded because state-inspected poultry plants (there are both state and federally inspected plants) were not required to meet the more rigorous Federal food-safety standards until 1967. Data from the 1967 Census were also excluded from chicken slaughter cost estimates because chicken traypack data were not collected until 1972.

LRD data provide detailed information on the physical quantities and dollar sales of many different products, physical quantities and prices paid for materials, and employment and wages for each establishment. The file also notes ownership and location information. Because the LRD contains data on individual plants over several Censuses, researchers can make comparisons for different plants during the same year, and can also trace changes in product and input mixes, costs, average prices, and concentration over time.

Variable Specifications

Factor price definitions and variable names are: total plant labor costs divided by total employees for labor costs (PLAB); cost of live poultry and unprocessed poultry meat divided by pounds of live poultry and unprocessed poultry meat for meat input costs (PMEAT); and, costs of energy, packing and packaging, and other material divided by pounds of live poultry and unprocessed poultry meat for other material costs (PMAT). The price of capital is an opportunity costs measure of the cost of capital. Following Allen and Lieu (1995), it is defined as (PCAP) = (OPPORTUNITY + NEW) / CAPACITY, where OPPORTUNITY = (machinery rental price) * (machinery book value) + (building rental price) * (building book value); NEW is the cost of new machinery and buildings; and, CAPACITY is buildings and machinery book value minus all retirements. Machinery or building rental prices (Bureau of Labor Statistics) are costs per dollar of machinery or buildings expenditure.

Most poultry firms in 1972 operated one plant but by 1992 most firms owned multiple plants. Although there could be other reasons, firms may be able to reduce costs by producing more specialized products in different plants. These possible firm effects are captured with a firm effects variable (SINGLE), defined as one for single plant firms and zero for multi-establishment firms.

Cost reducing technological change included improvements to production processes, refinements to existing inputs, plant specialization by bird species, and more balanced production scheduling. Bird species specialization (BIRD) is defined as one minus the percentage of inputs coming from live secondary birds and unprocessed poultry meat. For chickens, the residual is the percentage of live chickens in poultry inputs and for turkeys the residual is percentage of live turkeys in poultry inputs. More balanced production scheduling should be reflected in changing levels of production worker employment over the course of the year; thus, SEASON is defined as first quarter plant employment divided by fourth quarter plant employment. Cost-reducing technological change due to improvements in production processes and refinements to existing inputs are captured with time shift variables, ($TIME_i$), defined one for Census year I and zero otherwise.

We use two measures of product mix, BULK and WHOLE. The LRD files define output by Census product category, including chicken traypacks and chicken further processed products, such as sausages and luncheon meats, and turkey further processed products. BULK covers those products that do not fall into those categories, i.e. share of industry shipments accounted for by whole birds, poultry parts and deboned poultry packed in bulk containers, and other products, and was always definable. Increases in BULK imply less processing, and, thus, lower costs. But for any given value of BULK, plant costs can vary because parts and deboned product in bulk containers requires more processing than whole birds in bulk containers. In order to capture this effect, we use WHOLE, defined as the share of whole birds in industry output. Increases in WHOLE should be associated with reductions in processing costs.

Plant level data exists for BULK, but, since LRD data do no distinguish the types of products packed in bulk containers, only industry-level data from USDA are available for WHOLE. Because WHOLE only varies over time and product innovations impart a strong time trend, it cannot be included in a model with time shifters (collinearity collapses the model).[3] Thus, in our empirical analyses, we estimate models with time shifters but not WHOLE, and other models with WHOLE but not time shifters. We prefer

[3] The nature of the industry's product innovations mean that BULK increases steadily through time, but because BULK shows considerable variation across plants in any year, it does not generate collinearity problems with time shifters.

the models with WHOLE (an explicit representation of product innovation), for reasons described below.

Chicken

Estimation and Model Selection

A Gallant-Jorgenson likelihood ratio test was used to determine the model best able to explain plant production costs. In this test, we examine a test hypothesis relative to a maintained hypothesis, rejecting the maintained hypothesis in favor of the test model if the chi-square statistic exceeds a critical level. Table 3 summarizes the test models, maintained hypotheses, chi-square statistics, and the difference in the degrees of freedom between the two models (the number of restrictions) for several model variations for both chicken and turkey. There was insufficient model variance to estimate the model containing both time shifters and whole bird output because both variables are constant across all plants in a given year. We also examined homotheticity of the best performing model in order to assess how technology changes as plant size grows.

In the first model comparison, the most general model containing only price and output (PQ) is rejected in favor of a more restrictive PQBB model that adds the 13 variables associated with BULK and BIRD to the PQ model. A subsequent tests rejects the PQBB model in favor of the PQBBW model, which adds the 5 restrictions stemming from WHOLE to PQBB. This PQBBW model then becomes the maintained hypothesis and is compared against two model variations that add either single establishment firms (SINGLE) or seasonality (SEASON) to the PQBBW model. Neither of these additional variables improve model fit.

G-J tests alone may lead one to reject the PQBBW model in favor of PQBB and TIME model. However, we reject the PQBB and TIME model because cost estimates obtained from it suggest that plant production costs rise over time. We attribute this finding of regressive technological change to a misspecification error due to failure to account for the increase in labor, materials, and capital necessary to produce the higher value cut-up chicken that came to dominate output mix by 1992.

In the final test, we examine homotheticity of the PQBBW model by excluding all interaction terms between factor prices and output. We cannot reject the hypothesis that the PQBBW model is not homothetic, suggesting that the more general nonhomothetic model better explains model fit. Thus, we conclude that the best fitting model is nonhomothetic and nonhomogeneous and accounts for bird input specialization, bulk output share, and the whole bird output share. Appendix table A-1 contains the coefficients and standard errors for the first order and factor price interaction terms and table A-2 has the coefficients and standard errors for the remaining parameters in the model.

Factor Prices

The first order coefficients can be interpreted as cost shares at sample means. Factor shares at 1992 mean values (table 4) suggest that live chickens (PMEAT) account for about 73% of total costs, while labor (PLAB) and other materials (PMAT--primarily packaging) comprise 15 and 11 percent and the capital share is about 3 percent. Coefficients of the interactions of price of labor show that labor costs drop as bulk output share and output rise.[4]

The cooperating inputs of labor, capital, and other materials drive economies of scale, but make up only 27% of total costs. This relatively small share of costs for non-chicken factors of production and the large share of factor costs for live chickens means that technological scale economies have a limited effect on retail prices. But, since labor and other materials dominate capital share, small changes in either labor or capital costs have large impacts on returns to invested capital.

Price elasticities of factor demand (table 4) indicate downward sloping demand curves for labor, live chickens, materials, and capital and that demand for live chickens is the most inelastic and demand for capital the least inelastic. Allen elasticities suggest that all factor combinations, except for other materials and capital, are substitutes and that capital and labor and capital and live chickens offer the greatest substitution possibilities.

Economies of Scale

The top third of table 5 has cost elasticities, average cost indexes, and process cost shares (contributions of labor, other materials and capital to total costs) for various size plants with bulk share and whole bird share at sample mean values. Only the first and second order output terms and the interaction of output and whole bird share substantially affect cost elasticity estimates (equation 2). The first order coefficient for Q (.901 in table A-1) is the cost elasticity at the sample mean. The 20 percent cost index

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[4]The skewed distribution of factor shares gives rise to violations of monotonicity. Predicted factor shares are negative for capital in 11 percent, other materials in 5 percent, and labor in 0.1 percent of observations. There were no violations of the live chicken share. Most violations occurred in smaller plants during the earlier years of the study.

differential between the smallest and largest plants (one half and four times the sample mean size) illustrates a very sharp drop in costs for larger plants relative to their smaller rivals. This cost differential is consistent with the near-disappearance of small plants; likely contributed to the more than 300 percent increase in mean plant size; and, reduced the processing share of costs by over 2 percent over the 1972-92 period.

The 300 percent increase in average plant size over the 1972-92 period accompanied by approximately a 15 percent reduction in costs suggest substantial cost reductions with plant size. Moreover, these cost benefits show no sign of diminishing. The cost elasticity of the largest plants are well below one and below those of the second largest plants, suggesting very strong cost pressures to increase plant size. However, there are a number of unaccounted for factors, outside of the cost function, that may constrain plant size.[5]

Large plants must buy millions of live chickens from contract growers that must locate within 20 miles of the plant in order to avoid bird losses due to transportation stress during shipment to the plant and to be close to the plant-owned feed mill and hatcheries that supply feed and chicks. Growers must be able to dispose of large volumes of manure; avoid disease transmittal from adjacent chicken growing facilities; and, withstand the adverse effects of high temperature or other weather-related effects on birds.

Manure disposal appears to be particularly problematical in the Eastern Shore counties of Maryland and Delaware (Delmarva Peninsula). Chicken manure has recently been implicated in recent pfisteria outbreaks in the Chesapeake Bay and encouraged even more stringent regulation of chicken growers than

[5] Bill Roenigk of the National Chicken Council (interview on 3/25/99) indicates that a lack of growers and, more importantly, environmental concerns have limited chicken production growth in the Delmarva Peninsula.

that which existed previously. These restrictions have likely contributed to discouraging chicken plants from locating in this region. Broilers sold from Delmarva Peninsula farms dropped from 368 million to 364 million over the 1987-97 period, even though the number of broilers sold annually in United States increased from 4.28 billion birds to 6.71 billion birds over the same period.

Product demand may also limit plant size. If high speed chicken slaughter operations do not have uniform size chickens, they incur sharply higher production costs. However, the differentiated product market served by chicken slaughter plants requires chickens of different sizes: small chickens for chicken parts, medium-size birds for chicken traypacks, and large birds for deboned products. This fragmentation of production by product category means that the marketing area of any given plant is greater and that final product transportation costs are higher than those that would occur if all birds were of uniform size. Moreover, for branded products and more specialized products, the product market may not even be of sufficient size to require the production capabilities of a very large plant.

Product Mix and Other Variables

Modern chicken slaughter plants produce a wide variety of products ranging from whole chickens packed in bulk containers to traypacks, frankfurters, and luncheon meats. Whole birds packed in bulk containers undergo the least processing, while further processed products and traypacks have the most processing and much higher production costs. Thus, costs should drop as the bulk and whole bird shares rise.

The cost elasticity, cost index, and process costs changes as either bulk share of whole bird share rises (middle and bottom panels of table 5) illustrate processing costs and underscore the importance of controlling for product mix effects. Evaluating all other variables at sample mean values, the cost index drops 13 percent as the bulk share rises from 20 to 100 percent of the sample mean bulk share. Similarly, the cost index drops 13 percent as the whole bird share rises from 20 to 150 percent of the sample mean.

There do not appear to be economies of scope in either traypack or parts and deboned chicken production (the inverse of WHOLE). If there were, then the interactions of the bulk and whole bird shares with output would both be positive and significant rather than positive and insignificant and negative and insignificant (table A-1).

The coefficients involving chicken specialization suggest that use of a higher share of chickens (versus the alternative of unprocessed chicken meat or turkeys) leads to a higher labor and live chicken and lower capital cost shares. Other plant characteristics were also examined but did not improve model fit.

Researchers often use time shifters to control for disembodied technological change. However, including time shifter variables in the same model with whole bird share was not possible because there was insufficient model variance. Models including prices, output, bulk share, bird, and whole bird share but not time shifters (PQBBW-table 3) and prices, output , bulk share, bird, and time shifters but not whole bird share (PQBBT-table3) were estimated. The PQBBW model provides reasonable results. But, failure to account for labor intensive cut-up operations strongly biases costs upward and leads to serious misspecification error for the PQBBT model. Cost estimates across time at sample mean values for PQBBT suggest that production costs were higher in 1992 than in all of the other years except 1972 -- for 1977-87 cost indexes are 0.916, 0.894, and 0.928. Since these results imply regressive technological change, i.e. lost knowledge, we reject the PQBBT model.

Excluding time shift variables does not imply that we do not account for technological change.

Rather, technological change in chicken slaughter consisted of changes in product mix, live chicken and material usage, and plant size. We account for product mix technological change with the bulk and whole bird shares; factor-related changes through factor prices of meat and labor; and, size related technology with plant output.

Turkey

Model Selection and Factor Price Effects

Processing methods and the resulting cost function for turkeys is very similar to chicken slaughter. A Gallant-Jorgenson likelihood ratio test was used to assess model fit. Table 3 summarizes the test hypotheses, maintained hypotheses, and test statistics for several model variations. It is not possible to estimate a model containing both time shifters and whole bird output because of insufficient model variance; thus, a model containing whole birds but not time is compared to a model with time but not whole birds. Finally, homotheticity of the best performing model is examined to see whether technology changes with plant size.

In the model comparisons, the most general model containing only price and output (PQ) is rejected in favor of a more restrictive PQBS model that adds the 13 variables associated with BULK and SEASON to the PQ model. The PQBS model is rejected in favor of the PQBSW, which adds the 5 restrictions stemming from WHOLE to PQBB. Additional variables -- single establishment (SINGLE) and bird species specialization (BIRD) -- are rejected in favor of retaining the PQBSW model. Other tests show that neither BULK nor SEASON can be rejected. Seasonality did not meet the accept/reject threshold of a 99 percent level of confidence, but it does meet the less restrictive criterion of a 95 percent level. It is retained to illustrate that more balanced production schedules did affect plant costs, although only in a small way.

Including time shifters (TIME) in the model proves to be problematic. G-J tests suggest that PQBST provides a better model fit than the PQBSW model. However, we reject PQBST because cost estimates obtained from it suggest regressive technological change, i.e. plant production costs rise over time. Costs appear to rise because the PQBST model does not account for the increased processing required for producing cut-up and deboned products rather than whole birds (table 2). Since this regressive technological change is not rational, we reject the PQBST model. The final model test shows that the PQBSW model is not homothetic. Thus, the best fitting turkey model is nonhomothetic and nonhomogeneous and accounts for bulk output share, seasonality, and whole bird output share. Appendix table A-3 contains the coefficients and standard errors for the first order and factor price interaction terms and table A-4 has the coefficients and standard errors for the remaining parameters in the model.[6]

Estimated 1992 cost shares for turkey slaughter (table 4) show that live turkey dominates other factor shares, but is lower share than chickens and, also, cattle and hogs (MacDonald et al., 2000). Additionally, other materials expenses are much higher for turkey than either cattle, hogs, or chickens. We

[6] Monotonicity violations occurred mainly in smaller plants in the earlier part of the study. The arise from the skewed distribution of capital cost shares (6 percent of observations) and other materials (7 percent of observations), but not in labor and live turkeys.

attribute this greater share of other materials costs to the higher degree of further processing in turkey slaughter plants than in red meat plants. The much higher live turkey share of costs than other costs shares means that substantial scale economies in slaughter and fabrication translate into small scale economies in terms of total costs, but, if not passed through as product price changes, can lead to large changes in returns on invested capital.

Own factor price elasticities of demand and Allen elasticities of substitution for 1992 (table 4) are similar yet different than those found in chicken. All factors have downward sloping demand curves, but both live turkeys and capital are much more inelastic than chickens. Allen elasticities differ from chickens only in that capital and labor are stronger substitutes and capital weakly complements live turkeys rather than being a substitute.

Economies of Scale

Table 6 presents cost elasticities, cost indexes, and process cost shares for output, bulk share, and whole bird share for turkeys. The top panel shows that the elasticity of total costs with respect to output at the sample mean (column 2) is 0.919. Most importantly, notice that, as plant size varies from one half the sample mean plant size to four times the sample mean plant size (22 to 175 million pounds of output), the elasticity of total cost with respect to output and the average cost index decline from 0.925 to 0.852 and 1.046 to 0.828. These results are consistent with the 1000 percent increase in industry mean plant size and 3.7 percent decline in processing costs from 1967-92.

The second order output term indicates that cost elasticity continues to decline with plant size, suggesting that there is no foreseeable limit to plant expansion. However, factors other than those at the plant-level may encourage owners to shift production to different plants. The need to match bird size with market type is less important in turkeys than in chickens, but environmental concerns may be much more important. Relative to chickens, turkeys require more housing and other environmental controls in order avoid conditions that may impede turkey weight gain. However, turkey houses must also be located within 20 miles of the plant in order to avoid over stressing the birds during transit. Thus, turkey plant size may be constrained by the spacing required between turkey houses that is required to ensure that turkey diseases and localized weather conditions affecting one turkey house do not affect other turkey operations and undermine a plant's source of turkeys.

Manure disposal concerns may also prevent turkey plants from becoming too clustered or to locate in environmentally sensitive areas. Turkeys generate more manure than chickens because they are much larger birds. Typically, the manure is spread on farmland. However, in environmentally sensitive areas, such as the Delmarva Peninsula, the capacity of the soil to absorb manure nutrients is limited, causing potentially severe problems with runoff. Perhaps, for this reason, the Delmarva Peninsula is not a major turkey producing area.

Turkey growing may also be a more risky business than chicken growing. Turkeys require a longer grow-out period, suggesting that grower payments come less frequently and that there is a longer time in which any single turkey flock can be lost due to disease or be infected by disease from other flocks.[7] Additionally, turkey flock sizes must shrink during the summer months in order to reduce the threat of heat stress and then expand rapidly to meet market demands for the end-of-the-year holiday season, resulting

[7]Alice Johnson of the National Turkey Federation (interview of 5-10-99).

in greater variability in cash flows than in chicken growing and the need for carrying excess capacity during much of the year. Combined, the greater capital costs and greater risks associated with turkey growing relative to chickens may account for the greater degree of outright ownership of growing operations by turkey firms and may also encourage turkey firms to build more numerous, but smaller, slaughter plants in order to spread the risk of flock failures.

Turkey plants produce a wide variety of differentiated products, some of which are for smaller niche markets than more generic products. If product demand is limited and bird size must match market needs, then plant size would be limited by market size.

Product Mix, Seasonality, and other Plant Characteristics

Turkey plants produce a portfolio of products that include whole turkeys and deboned and cut-up turkey packed in bins, miscellaneous by-products; and, further processed products, such as turkey hams, frankfurters and luncheon meats. Since bulk products and whole birds require fewer inputs for converting one pound of turkey into a finished product, costs should decline as the bulk and whole bird shares rise.

The cost elasticity, cost index, and process cost changes for various levels of bulk and whole bird shares are reported in table 6 (middle and bottom panels). Costs decline about three percent as the ratio of the bulk share to the sample mean bulk share rises from 0.20 to 1.00, and, costs decline about five percent as the ratio of the whole bird share to the sample mean share rises from 0.20 to 1.20.

Turkey slaughter plants have traditionally, sharply increased production for the end-of-year holiday season, but have recently begun producing on much more balanced schedules. This imbalanced production schedule could require much plant capacity to be idle during the year and lead to sharply higher costs.

However, seasonality was found to have only a modest effect on plant costs (tables 6 and A.4). Other variables including single establishment plants and percent live turkeys were also tested but rejected.

Time shifters and whole bird share could not be included in the same model because insufficient model variance causes the model to collapse. Results for the PQBST model show an improvement in model fit over the PQBBW model (table 3), but also suggest regressive technological change. Estimates from the model suggest that sample mean size plants in 1992 had higher costs than sample mean size plants in 1967 and 1972; plants that are twice the sample mean size in 1992 had higher costs than 1967-77 plants that are twice the sample mean size; and the costs of sample mean size plants increased by more than 20 percent over the 1967-92 period.

By excluding time shifters from the model, we cannot account for disembodied technological change. However, the model explicitly controls for other types of technological changes, including product mix and seasonality changes and factor and output biased changes.

Chickens and Turkeys Compared to Cattle and Hogs Results

<u>Shares and Own Factor Price Effects</u>

Results for chicken and turkey differ substantially from those reported for cattle and hog slaughter. Relative to chickens and turkeys, the cattle cost share of 83.7 percent is much higher, labor and other materials cost shares (8.2 and 5.1 percents) are much lower, and capital about the same. Hog slaughter has a much higher capital share (8.1 percent) than the other slaughter industries. Other cost shares are intermediate to cattle and chicken and turkey.

Cost share differences could be due to processing differentials in the cattle, hog, chicken and turkey plants. Carcasses and primals are major products for cattle slaughter operations, whereas only about 20 percent of chickens and 45 percent of turkeys are in whole or near whole form. Chicken and turkey slaughter plants also convert much more of their chicken and turkey meat inputs into ready-to-cook parts, traypacks, luncheon meats, and other further processed products than do cattle, and to a lesser extent, hog slaughter plants (none for cattle and 17.4 percent for hogs versus 22 and 47.9 percents for chickens and turkeys).[8]

The labor, material, and capital own price elasticities for chicken, turkey, and hog slaughter are similar to those for cattle slaughter (MacDonald, et al, 2000), but meat own price elasticity for cattle differs substantially from the others. A 10 percent price increase for meat inputs has almost no effect on the demand for cattle, but would elicit about a 1 percent drop in the demand for hog or live chicken or turkey inputs. Thus, "value added" cost functions ignoring animal input costs may provide accurate results for cattle but misleading ones for the others.

The much more sensitive response of chicken, turkey, and hog factor demand to animal prices than that of cattle may stem from control over animal inputs. It takes 3 years to raise a calf to slaughter-ready weight, but only about 8 weeks for chicks (more for poults and pigs). Additionally, cattle slaughter plants cannot directly influence animal production or breeds because they have little direct relationship to cattle growers and almost no direct control over animal breeding and care practices. Chicken and turkey slaughter plants, on the other hand, provide most inputs, including the chicks and poults, and, along with

[8]Based on unpublished Census data for hogs and Ollinger er al (2000).

hog slaughter plants, contract directly with growers for finished animals.

Economies of Scale and the Importance of Controlling for Product Mix

Failure to account for product and input mix biases estimated scale economies for all the slaughter industries, but particularly for chicken and turkeys. The cost elasticity at sample mean prices and output for chickens for the price and quantity (PQ) model is 0.953, but this drops to 0.901 at sample mean output after controlling for product and input mix (table 7). Similarly, for turkeys, cost elasticity drops from 0.977 for the PQ model to 0.919 after controlling for product mix. By contrast, the PQ model for cattle and hogs have elasticities of 0.959 and 0.980 and the models with controls for product and input mixes have elasticities of 0.932 and 0.926.

Differences in the importance of product mix among the four slaughter industries are even more dramatic for large plants. Large chicken and turkey plants have higher elasticities than their smaller competitors, according to the PQ model, but much lower elasticities according to the models that control for product and input mixes (table 7). Large cattle and hog slaughter plants have higher elasticities than their smaller counterparts with or without controls for product and input mixes.

Conclusion

Results of cost function analyses of the chicken and turkey slaughter industries provide evidence of sizeable scale economies that grow with increases in plant size. The largest plants have production costs that are about 8 percent lower than plants one half their size and about 20 percent lower than plants one eighth their size. Cost advantages of these magnitudes for both chicken and turkey slaughter help explain (1) the near disappearance of small plants; (2) the shift in market share held by the largest plants from less than 30 percent in 1967 to over 80 percent in 1992; and, (3) the 300 and 1100 percent increases in plant sizes over the 1967-92 period.

Chicken and turkey scale economies are much sharper than those reported for cattle and hogs (MacDonald, et al., 2000). Poultry plants that are four times larger than plants at the sample mean plant sizes have average costs that are over 15 percent lower, while red meat slaughter plants that are four times larger than sample mean plants have average 7 percent lower average costs.

Implications of product mix effects are important for accurate estimates of chicken and turkey slaughter costs and economies of scale. Poultry slaughter cost models that do not control for either the bulk share of output or the whole bird share of output have cost elasticities that are over 5 percent higher than cost models with these controls. Failure to control for product mix also substantially biases estimated scale economies because chicken and turkey slaughter plants increased their processing as they grew in size. This level of bias is much greater in chicken and turkey slaughter (13 percent) than for cattle and hog slaughter (5 percent).

Available data could not explain the limits to plant size. We speculate that higher transportation costs for both final products and feed for growers, environmental restrictions, and plant specialization by bird breed may impede growth in plant size, but no evidence was found to support these hypothesis. Thus, the question of the extent of scale economies requires further research.

Table 1: Structural Change for Poultry Slaughter and Processing Plants.

	1967	1972	1977	1982	1987	1992
Plants	-------------------------------Number-------------------------------					
Chickens	140	194	179	134	125	144
Turkeys	75	59	50	36	31	30
Poultry Processing	d	21	26	32	58	65
Concentration	----------Market Share Held by Four Largest Firms-----------					
Chickens	23	18	22	32	42	41
Turkeys	28	41	41	40	38	35
Poultry Processing	49	35	48	37	36	46
Large Plant Share	----Market Share Held by Plants with Over 400 Employees----					
Chickens	29	34	45	65	76	88
Turkeys	16	15	29	35	64	83
Poultry Processing	d	41	51	53	65	71

Source: Longitudinal Research Database, U.S. Bureau of the Census. Cells labeled ‘d’ contain data that cannot be disclosed, in order to retain respondent confidentiality. Large plants are defined as those with more than 400 employees, and share is of industry value of shipments.

Table 2 : Processed Poultry, including chicken traypacks and turkey parts, become a major component of slaughter plant output.

	-------------Chicken-------------			------Turkey------	
Year	Traypacks	Lunch meat, Sausage, etc.	Parts[1]	Lunch meat, Sausage, etc	Turkey Parts[1]
	--------------percent--------------			-----percent----	
1963	n.a.	n.a.	12.5	n.a.	3.3
1972	11.0	2.6	28.4	8.5	15.7
1982	15.4	3.1	47.6	13.1	29.1
1992	18.9	3.1	78.5	16.8	55.1

Source: Longitudinal Research Database, U.S. Census Bureau and other sources as noted.
[1] ERS, U.S. Egg and Poultry Statistical Series, 1960-90 (1991) for 1963-87 and ERS estimates for 1992.

Table 3: Model Selection Tests for Various Chicken and Turkey Slaughter Cost Functions.

Chicken			Turkey			d.f
Maintained Hypothesis	Test Hypothesis	Chi-square[1]	Maintained Hypothesis	Test Hypothesis	Chi-square[1]	
P and Q	P, Q, BULK, BIRD (PQBB)	67***	P and Q	P, Q, BULK, SEASON (PQBS)	33***	13
PQBB	PQBB and WHOLE (PQBBW)	17***	PQBS	PQBS and WHOLE (PQBSW)	24***	5
PQBBW	PQBBW, and SINGLE	6	PQBSW	PQBSW, and SINGLE	5	8
PQBBW	PQBBW, and SEASON	-1	PQBSW	PQBSW and BIRD	-10	5
PQBBW	PQ, BULK, and WHOLE	-33***	PQBSW	P, Q, SEASON, WHOLE	-35**	7
PQBBW	P, Q, BIRD, and WHOLE	-56***	PQBSW	P, Q, BULK, WHOLE	-16***	7
PQBB	PQBB, TIME (PQBBT)[2]	61***	PQBS	PQBS and TIME (PQBST)[2]	49***	20
PQBBW	Homothetic: PQBBW	-19***	PQBSW	Homothetic: PQBSW	-20***	3

*** significant at 99% level; ** significant at 95% level.
Notes: Chi-square equals the Gallant-Jorgenson statistic of maintained minus test hypotheses with degrees of freedom as shown in last column under d.f. There are 694 observations in 1972, 77, 82, 87, and 92 for chicken; 314 observations in 1967, 72, 77, 82, 87, and 92. for turkey.
1. Test hypothesis is retained if G-J test result has 95% or greater confidence level.
2. PQBBT and PQBST are rejected because they have regressive technological change, which occurs because these models do not account for greater parts and deboned chicken production.

Table 4: 1992 Own factor price and Allen elasticities evaluated at the sample mean for Chicken and Turkey Slaughter Plants.

	--------------Factor Price Variables---------------			
	PLAB	PMEAT	PMAT	PCAP
CHICKEN				
Estimated Factor Shares	.1500	.7328	.1124	.0256
å$_{ii}$ (own factor price)	-0.313	-0.140	-.258	-1.964
ó$_{ij}$ (Allen)				
PLAB	-2.206	0.164	0.929	2.108
PMEAT		-0.205	0.224	2.604
PMAT			-1.822	-0.818
PCAP				-59.999
TURKEY				
Estimated Factor Shares for 1992	.117	.679	.195	.009
å$_{ii}$ (own factor price)	-0.464	-0.094	-.269	-0.998
ó$_{ij}$ (Allen)				
PLAB	-3.548	0.293	0.671	8.922
PMEAT		-0.143	0.294	-0.020
PMAT			-1.408	-0.813
PCAP				-62.86

Note: All values are evaluated at the sample mean. The own price factor demand elasticities (å$_{ii}$) are calculated holding output and other factors constant, while the elasticities of substitution (ó$_{ij}$) are calculated using Allen's formula.

Table 5: How Chicken slaughter costs vary as plant size and product mix changes.

Output[1]	Cost Elasticity	Cost Index	Process Cost Share[2]	Output to Sample Mean	Output to 1972 Mean	Output to 1992 Mean
--Scale Effects---						
37.4	0.925	1.058	32.4	0.50	0.99	0.26
74.8	0.901	1.000	31.6	1.00	1.97	0.53
149.6	0.877	0.927	30.8	2.00	3.95	1.06
299.2	0.852	0.850	29.9	4.00	7.90	2.11
-------------------------------Product Mix Effects: Bulk Share[3]-------------------------------------						
Bulk Share[2]	Cost Elasticity	Cost Index	Process Cost Share[2]	Bulk Share to Sample Mean	Bulk Share to 1972 Mean	Bulk Share to 1992 Mean
16.8	-0.066	1.145	31.6	0.20	0.19	0.22
42.0	-0.084	1.050	31.6	0.50	0.49	0.54
67.2	-0.093	1.021	31.6	0.80	0.78	0.86
84.0	-0.097	1.000	31.6	1.00	0.97	1.08
-------------------------------Product Mix Effects: Whole Bird Share[4]----------------------------						
Whole Share[2]	Cost Elasticity	Cost Index	Process Cost Share[2]	Bird Share to Sample Mean	Bird Share to 1972 Mean	Bird Share to 1992 Mean
9.1	-0.216	1.114	37.7	0.20	0.11	0.43
22.9	-0.216	1.047	34.2	0.50	0.27	1.06
36.6	-0.216	1.015	32.4	0.80	0.42	1.66
45.7	-0.216	1.000	31.6	1.00	0.53	2.08
68.6	-0.216	0.974	30.0	1.50	0.78	3.12

1. In millions of pounds.
2. in percentages.
3. Bulk Share is one minus chicken traypacks and further processed products.

4.Whole Bird Share is one minus share of deboned and cut-up chicken.

Table 6: How Turkey slaughter costs vary as plant size and product mix changes.

----------Scale Effects----------						
Output[1]	Cost Elasticity	Cost Index	Process Cost Share[2]	Output to Sample Mean	Output to 1972 Mean	Output to 1992 Mean
21.9	0.936	1.046	35.0	0.50	1.37	0.19
43.7	0.919	1.000	33.8	1	2.74	0.38
87.4	0.902	0.897	32.6	2.0	5.48	0.75
174.8	0.884	0.828	31.3	4.0	10.96	1.51
----------Product Mix Effects: Bulk Share[3]----------						
Bulk Share[2]	Cost Elasticity	Cost Index	Process Cost Share[2]	Bulk Share to Sample Mean	Bulk Share to 1972 Mean	Bulk Share to 1992 Mean
17.9	-0.026	1.030	35.1	0.20	0.18	0.22
44.8	-0.028	1.014	34.4	0.50	0.45	0.55
71.6	-0.029	1.005	34.0	0.80	0.72	0.88
89.5	-0.029	1.000	33.8	1.00	0.90	1.10
----------Product Mix Effects: Whole Bird Share[4]----------						
Whole Share[2]	Cost Elasticity	Cost Index	Process Cost Share[2]	Bird Share to Sample Mean	Bird Share to 1972 Mean	Bird Share to 1992 Mean
15.5	-0.128	1.048	36.7	0.20	0.16	0.34
38.8	-0.128	1.020	35.0	0.50	0.41	086
62.0	-0.128	1.006	34.2	0.80	0.66	1.38
77.5	-0.128	1.000	33.8	1.00	0.82	1.73
96.9	-0.128	0.995	33.5	1.20	1.03	2.16

1. In millions of pounds.
2. in percentages.

3. Bulk Share is one minus further processed products.
4.Whole Bird Share is one minus share of deboned and cut-up turkey.

Table 7: Cost elasticity estimates for large and mean size plants in four slaughter industries: The importance of scale economies and product mix.

Plant Size[1]	Product and Input Mix Controls[2]	-------Slaughter Class-------			
		chicken	turkey	cattle	hog
		------------Cost Elasticities----------			
Mean	No	0.953	0.977	0.959	0.980
Large	No	0.985	0.978	0.971	1.000
Mean	Yes	0.901	0.919	0.932	0.926
Large	Yes	0.852	0.884	0.947	0.946

Notes:
1. Mean plant size is at the sample mean for each product class, while large plants are four times the sample mean.
2. Product mix includes all product-related output variables that significantly affect output: bulk share and whole bird shares for chickens and turkeys and one minus share of carcass production for cattle and hogs. Input mix is liveweight animal inputs of primary species as share of all meat inputs (i.e. cattle weight divided by all meat inputs for cattle slaughter). Input mix not included in turkey model because not significant to model fit.
3. Cattle and hog results are based on MacDonald et al. (2000).

Table A-1: Chicken slaughter cost function parameter estimates: First order terms and factor price interaction terms.

		------------------interacted with------------------			
Variable	1st order	PLAB	PMEAT	PMAT	PCAP
	---------------Coefficients and standard errors----------------				
Intercept	-0.066*** (.011)	-	-	-	-
PLAB	.142*** (.003)	.077*** (.008)	-.081*** (.006)	-.001 (.002)	.005 (.005)
PMEAT	.684*** (.008)		.120*** (.015)	-.075*** (.003)	.036*** (.014)
PMAT	.142*** (.002)			.085*** (.002)	-.008*** (.003)
PCAP	.032*** (.008)				-.032[1]
B	-.097*** (.017)				
A	-.216** (.109)				
Q (lbs)	.901*** (.015)				
W	-.067*** (.026)				

Note: Translog cost function estimation for chicken slaughter, 1972-1992. Since all variables are standardized at their means, first order coefficients can be interpreted as elasticities at the sample means. There are 694 observations. * significant at 90% level; ** significant at 95% level; *** significant at 99% level.

1. Standard error could not be estimated.

Table A-2: Chicken slaughter cost function parameter estimates: First order terms and bulk share output, animal inputs, output, and whole bird share of output interaction terms.

		----------------interacted with---------------			
Variable	1st Order	B	A	Q	W
	---------------Coefficients and standard errors----------------				
Intercept	-0.066*** (.011)	-	-	-	-
PLAB	.142*** (.003)	-.0035*** (.0009)	.076*** (.014)	-.022*** (.002)	-.001 (.007)
PMEAT	.684*** (.008)	.0001 (.003)	.113*** (.037)	.012* (.007)	.038* (.024)
PMAT	.142*** (.002)	.0003 (.0006)	.035*** (.009)	.003* (.0016)	.001 (.005)
PCAP	.032*** (.008)	.0031 (.003)	-.189*** (.037)	.007 (.007)	-.038* (.023)
B	-.097*** (.017)	-.019*** (.004)	-.029 (.044)	.0005 (.003)	-
A	-.216** (.109)		-.206*** (.057)	.041 (.061)	-
Q (lbs)	.901*** (.015)			-.013 (.011)	-.035 (.026)
W	-.067*** (.026)				-

Note: Translog cost function for chicken slaughter plants, 1972-1992. Since all variables are standardized at their means, first order coefficients can be interpreted as elasticities at the sample means. There are 694 observations. * significant at 90% level; ** significant at 95% level; *** significant at 99% level.

Table A-3: Turkey slaughter cost function parameter estimates: First order terms and input price interaction terms.

		-----------------interacted with----------------			
Variable	1st order	PLAB	PMEAT	PMAT	PCAP
		---------Coefficients and standard errors---------			
Intercept	-0.208*** (.018)	-	-	-	-
PLAB	.131*** (.005)	.053*** (.012)	-.061*** (.010)	-.008** (.004)	.017** (.007)
PMEAT	.662*** (.007)		.161*** (.013)	-.089*** (.005)	-.011 (.007)
PMAT	.191*** (.004)			.103*** (.003)	-.006 (.0035)
PCAP	.016*** (.005)				-.0002[1]
B	-.029 (.033)				
S	.021 (.017)				
Q (lbs)	.919*** (.025)				
W	-.128** (.050)				

Note: Translog cost function estimation for turkey slaughter, 1967-1992. There are 314 observations. Since all variables are standardized at their means, first order coefficients can be interpreted as elasticities at the sample means. * significant at 90% level; ** significant at 95% level; *** significant at 99% level.
1. Standard error could not be estimated.

Table A-4: Turkey slaughter cost function parameter estimates: First order terms and bulk share of output, seasonality, output, and whole bird share of output interaction terms.

		---------------interacted with---------------			
Variable	1st Order	B	S	Q	S
		-------Coefficients and standard errors-------			
Intercept	-0.208***	-	-	-	-
	(.018)				
PLAB	.131***	-.0082***	.0023	-.015***	.002
	(.005)	(.0026)	(.002)	(.005)	(.016)
PMEAT	.662***	.0081***	-.0061**	.0178***	.018
	(.007)	(.003)	(.003)	(.006)	(.019)
PMAT	.191***	-.0067***	.002	.0042	.004
	(.004)	(.002)	(.002)	(.004)	(.011)
PCAP	.016***	.0068***	.0018	-.007	-.022
	(.005)	(.002)	(.002)	(.005)	(.014)
B	-.029	-.002	-.004	-.002	-
	(.033)	(.008)	(.003)	(.007)	
S	.021		.005	-.0015	-
	(.017)		(.005)	(.008)	
Q (lbs)	.919***			-.025	-.039
	(.025)			(.027)	(.056)
W	-.128**				-
	(.050)				

Note: Results of estimation of translog cost function for turkey slaughter plants, 1967-1992. Since all variables are standardized at their means, first order coefficients can be interpreted as elasticities at the sample means. Quadratic (on diagonal) and interaction terms from estimation of translog cost function.
* significant at 90% level; ** significant at 95% level; *** significant at 99% level.

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